

# Simulation of realistic SLR observations to optimize tracking scenarios

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# Introduction: Overview

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- Simulation of Satellite Laser Ranging measurements to GNSS and geodetic satellites.
- Calculation of pseudorange due to geometry, then apply:
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    - Corrections
    - Noise
- Synthetic observations upon which comparison and optimization can be done.
- Impact of target selection.

# Introduction: Procedure

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- **Bernese GNSS Software.**
- **Independent noise generation for each observation.**
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    - **Adding/removing satellites at other epochs.**
    - **Exchanging satellites at specific epoch.**
- **Observation selection separate from simulation.**

# Introduction– ILRS Tracking Campaigns

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- **Campaign1: August 01 – September 30, 2014**
  - All GNSS satellites (on ILRS priority list, 18 satellites); more if able
  - Three sets of two normal points distributed over transit; normal point includes 1000 FR points or last 5 minutes, whichever is shorter
- **Campaign2: November 22, 2014– February 28, 2015**
  - Six GLONASS as first priority, Beidou and Galileo as second priority , remaining GLONASS as third priority
  - minimum three segments along each pass with three NPTs in each segment
- **Campaign3: August 20 – October 16, 2015**
  - Six GLONASS as first priority, Compass–M3 and Galileo as second priority, remaining GLONASS as third priority
  - Nine NPTs over the pass; 3 during the ascending/early region, 3 in the central region, 3 in the descending/late region of the pass

# Introduction– ILRS Tracking Campaigns

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- **Common Results**
  - Need more data
  - Few stations could fulfill requirements all the time
  - More daylight data
- **ILRS can handle tracking of all the required satellites (for now).**
- **Simulation might give a definite answer in future.**

# Simulation– Requirements

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- Ability to generate synthetic SLR measurements to satellites in form of NP.
- Include station/satellite specific noise handling.
- Based on final orbit products (or predictions).
- Possibility to alter observations as needed.
- Lie within the accuracy requirements of the ILRS.

# Simulation – Implementation

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- **Separate SLR mode within Bernese GNSS Software Simulation tool.**
  - Selectable noise
  - Selectable stations
  - Selectable observation list
- **Result are range observation files.**

# Simulation – Observation Selection

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YYYY	MM	DD	STAT	TIME IN SECONDS	PRN	
****	**	**	****	*****	***	*
2015	05	06	7810	32046.185902247878	108	1
2015	05	06	7810	32126.060302248032	108	1
2015	05	06	7810	34742.648702320352	107	1
2015	05	06	7810	34862.552302311269	107	1
2015	05	06	7810	35154.578702318162	107	1
2015	05	06	7810	36243.455102316861	108	1
2015	05	06	7810	36376.229502318871	108	1
2015	05	06	7810	40050.113102219737	111	1
2015	05	06	7810	50219.056302341145	111	1
2015	05	06	7810	51928.352112342225	121	1
2015	05	06	7810	51932.583932335045	121	1
2015	05	06	7810	51936.500912335854	121	1
2015	05	06	7810	51942.945872333563	121	1
2015	05	06	7810	51946.872112332734	121	1
2015	05	06	7810	51951.641012342428	121	1
2015	05	06	7810	51958.623052340256	121	1
2015	05	06	7810	51962.188152332608	121	1
2015	05	06	7810	51967.808972341074	121	1
2015	05	06	7810	51972.374152341465	121	1
2015	05	06	7810	51977.856072334798	121	1
2015	05	06	7810	51982.106412339985	121	1
2015	05	06	7810	51987.792052336998	121	1
2015	05	06	7810	51992.042392342613	121	1
2015	05	06	7810	51997.524312334826	121	1
2015	05	06	7810	52001.691312335461	121	1
2015	05	06	7810	52007.451032332443	121	1
2015	05	06	7810	52018.155592334660	121	1
2015	05	06	7810	52022.054052340201	121	1
2015	05	06	7810	52027.526712332408	121	1
2015	05	06	7810	52031.951052338896	121	1
2015	05	06	7810	52037.587572334320	121	1
2015	05	06	7810	52042.560972338986	121	1
2015	05	06	7810	52047.119922336395	121	1
2015	05	06	7810	52052.738022335390	121	1
2015	05	06	7810	52056.818052335875	121	1
2015	05	06	7810	52061.561202337041	121	1
2015	05	06	7810	54224.806702237183	123	1
2015	05	06	7810	61700.233082270584	124	1
2015	05	06	7810	62868.262582268966	113	1
2015	05	06	7810	63549.433102269177	113	1
2015	05	06	7810	63843.317902267241	113	1
2015	05	06	7810	63903.531902260132	113	1
2015	05	06	7810	78878.631902225781	103	1
2015	05	06	7810	79022.709502223472	103	1
2015	05	06	7810	79281.893502318562	102	1
2015	05	06	7810	79286.484302322424	102	1



# Simulation – Noise

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- **White noise**
  - Selectable
  - Elevation dependent sigmas
  - Repeatable
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- **Normal distributed noise**
  - Different parameters for each station/satellite combination.
  - Resembling bin RMS found in NP files.

# Simulation – First Results

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- **First Results**
  - **Without noise**
  - **White noise**
  - **Normal distributed noise**

# Simulated observation file

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GPSSIM2      : simulate SLR data to GNSS satellites 18433
MEASUREMENT TYPE: RANGE                      CREATED : 26-MAY-16 15:37
REFERENCE EPOCH : 2015-05-06 0:37:43 (126)  MODIFIED: 26-MAY-16 15:37

# DIFFERENCES      : 0          FORMAT NUMBER      : 6
# FREQUENCIES      : 1          SESSION IDENTIFIER  : 126S
# SATELLITES       : 0          SUBSESSION IDENTIF. : 5
# EPOCHS           : 77051      OBS. INTERVAL (S)  : 1.000000
# FLAGGED EPOCHS   : 0          REMARK NUMBER      : 0

STATION NAME      : ZIMM 14001S007
OPERATOR NAME     :
RECEIVER TYPE     : SIMULA DEFAULT
ANTENNA TYPE      : SIMULA      NONE
RECEIVER/ANTENNA  : 0 / 0

CLOCK CORRECTION: POLYNOMIAL DEG 0

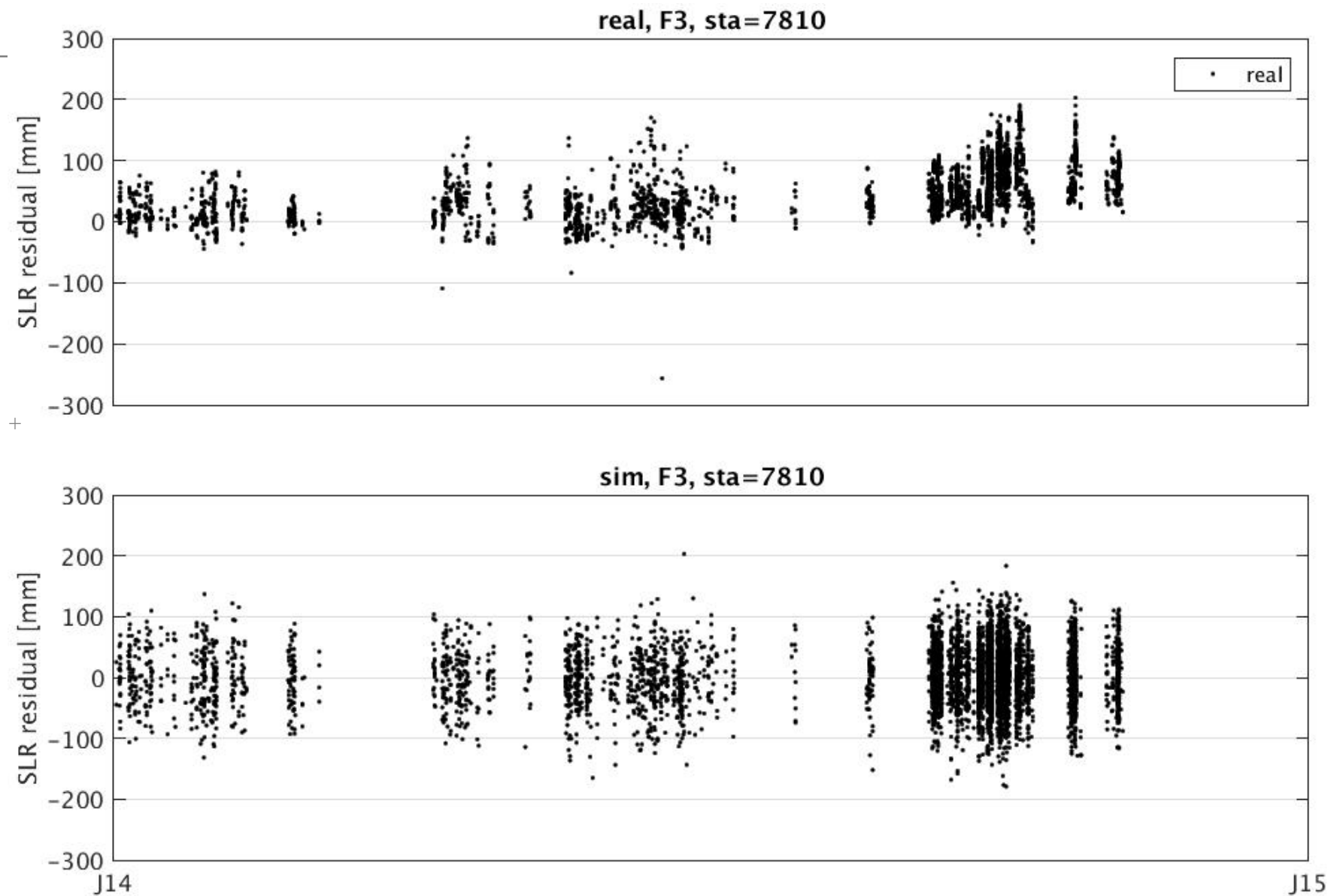
POS,ECCENTR. (M): 0.0000 0.0000 0.0000

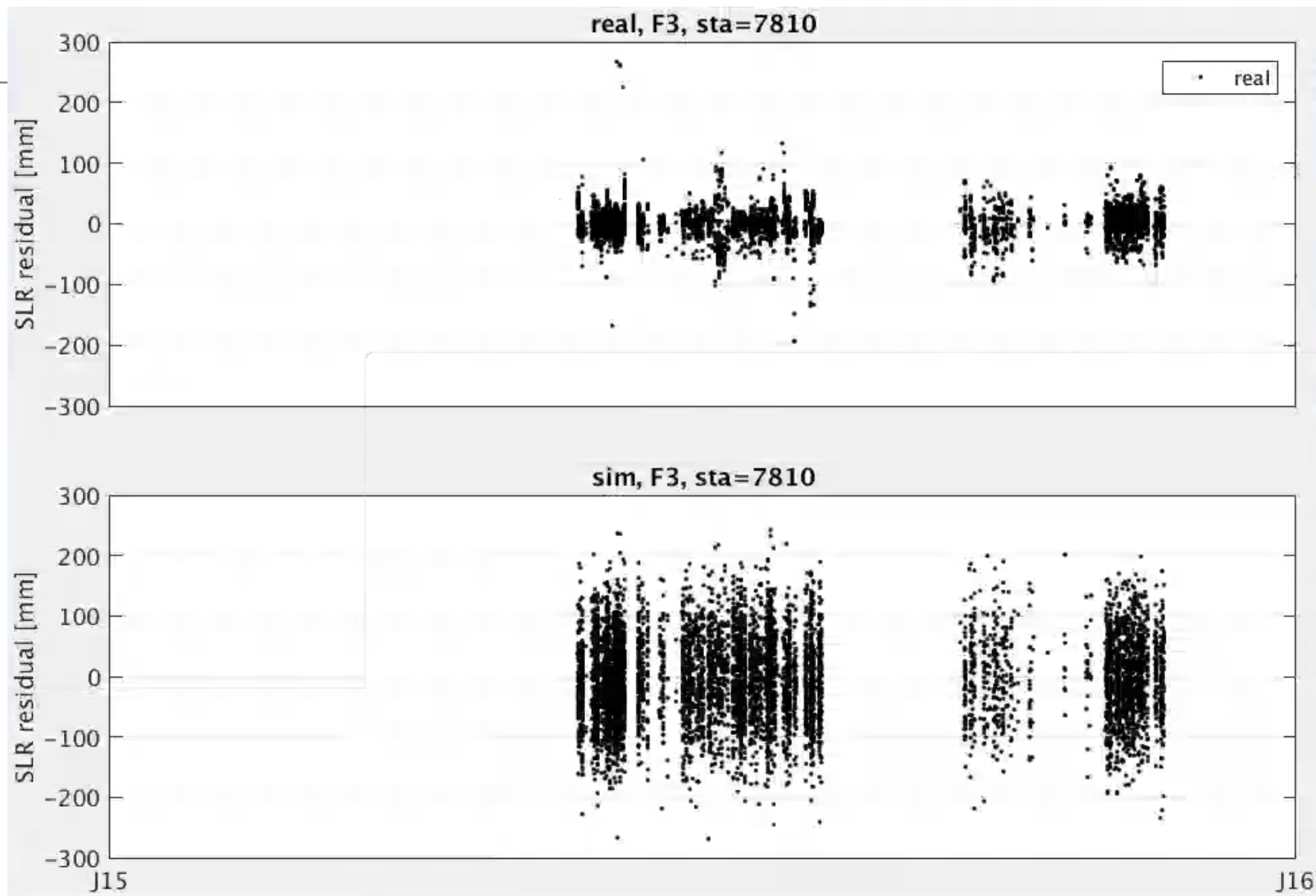
SAT   #L1-OBS OK #L1-OBS BAD #L2-OBS OK #L2-OBS BAD Station1 Station2
      #L1-OBS OK #L1-OBS BAD #L2-OBS OK #L2-OBS BAD Obstype1 Obstype2 Obstype1 Obstype2

L1,L2 OBSERVATIONS:
OBS.N  TIME  F #S  RANGE (M)  FFS SA  ...  AT THE END: DATE, FRACT.(S), CLOCK (S)
  1  8:54:06  1  21468293.625  0 108 15-05-06  0.000000000 -0.000000000
121  8:55:26  1  21555114.393  0 108 15-05-06  0.000000000 -0.000000000
413  9:39:02  1  21771033.657  0 107 15-05-06  0.000000000 -0.000000000
903  9:41:02  1  19687406.544  0 107 15-05-06  0.000000000 -0.000000000
983  9:45:54  1  19660905.183  0 107 15-05-06  0.000000000 -0.000000000
5100 10:04:03  1  19554801.692  0 108 15-05-06  0.000000000 -0.000000000
5233 10:06:16  1  19595476.023  0 108 15-05-06  0.000000000 -0.000000000
19701 11:07:30  1  19678965.284  0 111 15-05-06  0.000000000 -0.000000000
26550 13:56:59  1  21223037.746  0 111 15-05-06  0.000000000 -0.000000000
26555 14:25:28  1  21225342.651  0 121 15-05-06  0.000000000 -0.000000000
26562 14:25:32  1  21228575.446  0 121 15-05-06  0.000000000 -0.000000000
26576 14:25:36  1  21235060.791  0 121 15-05-06  0.000000000 -0.000000000
26582 14:25:42  1  21237848.203  0 121 15-05-06  0.000000000 -0.000000000
26586 14:25:46  1  21239709.436  0 121 15-05-06  0.000000000 -0.000000000
    
```

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# White noise





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## Normal distributed noise

# Noise parameters

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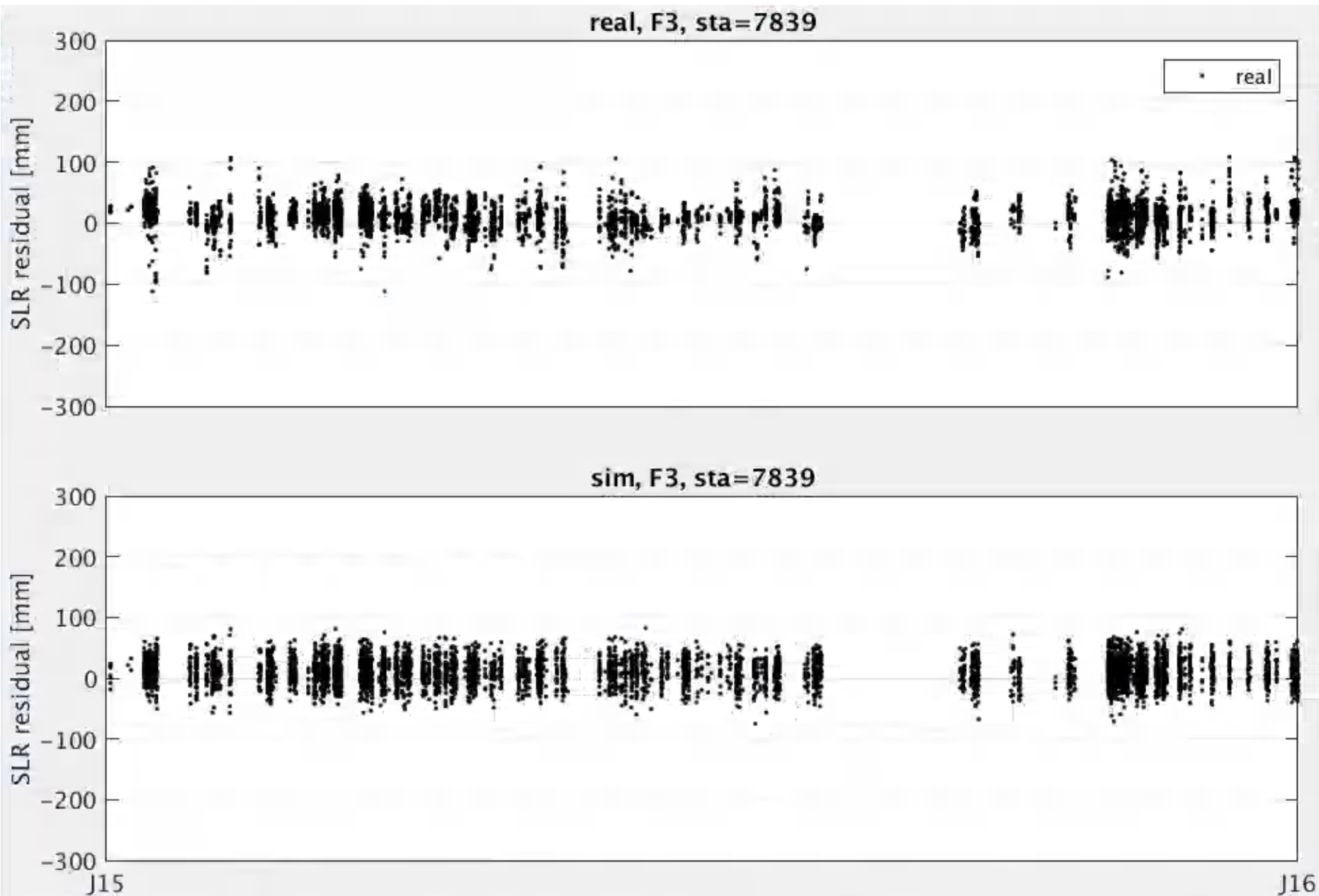
+

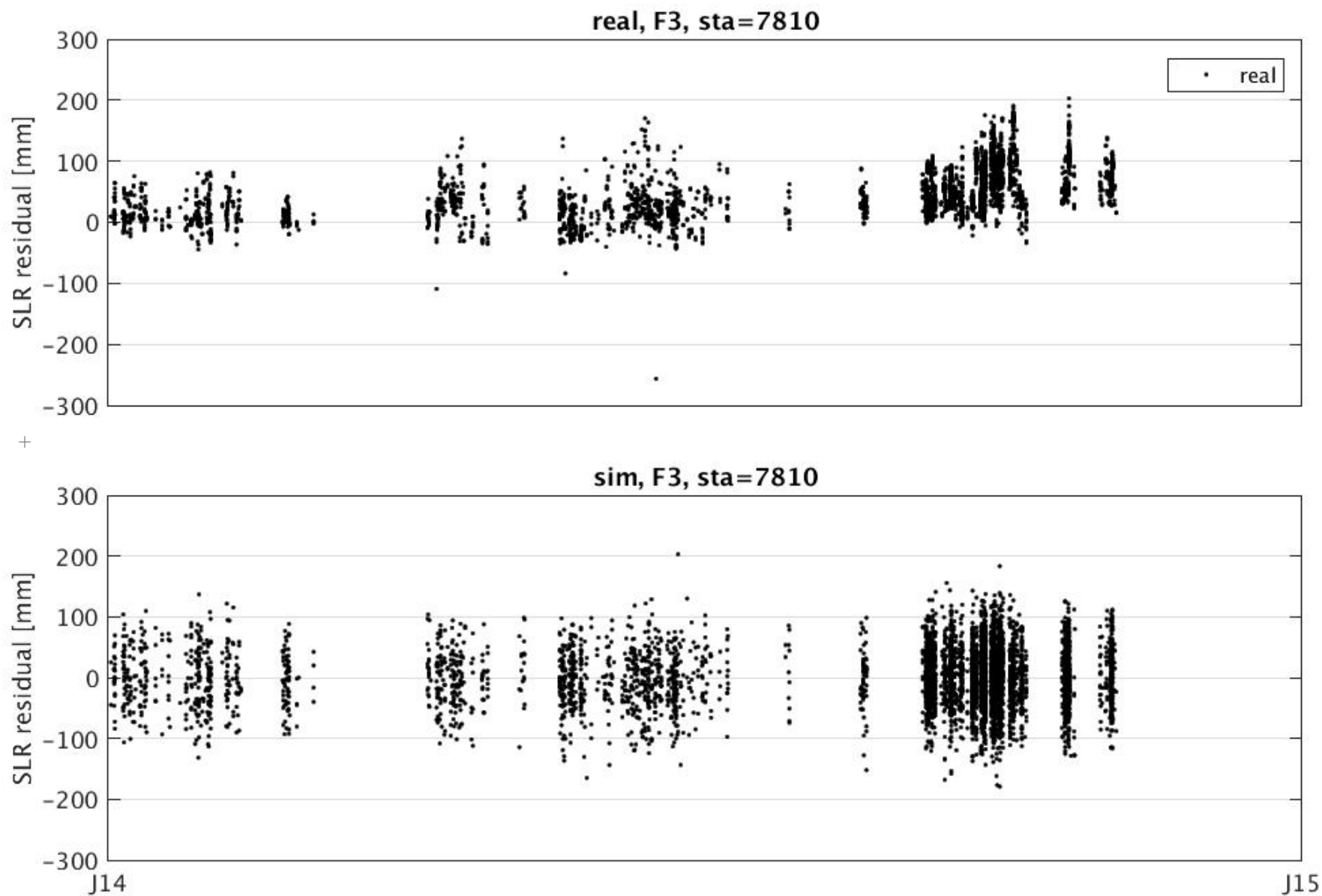


# Noise parameters

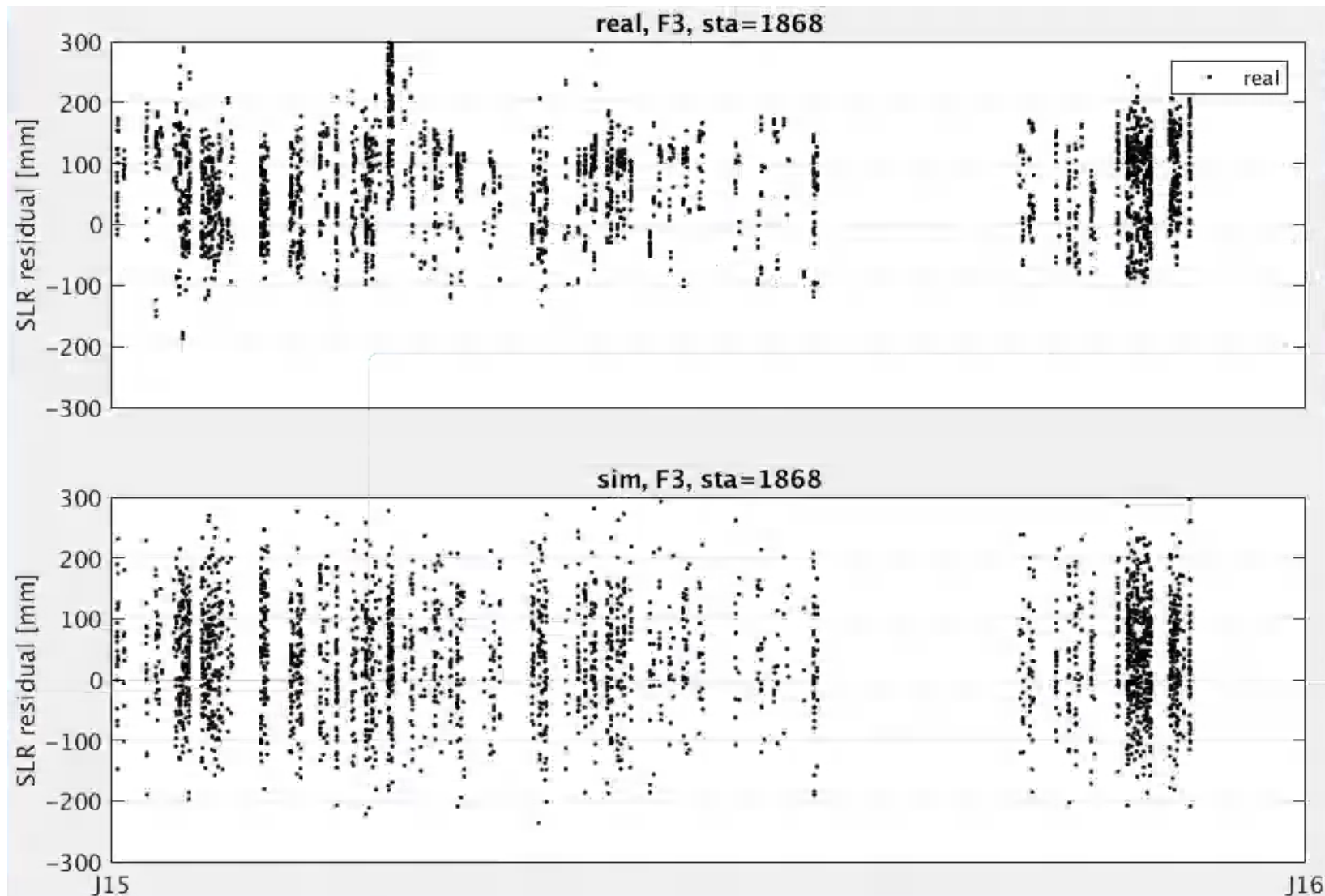
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+

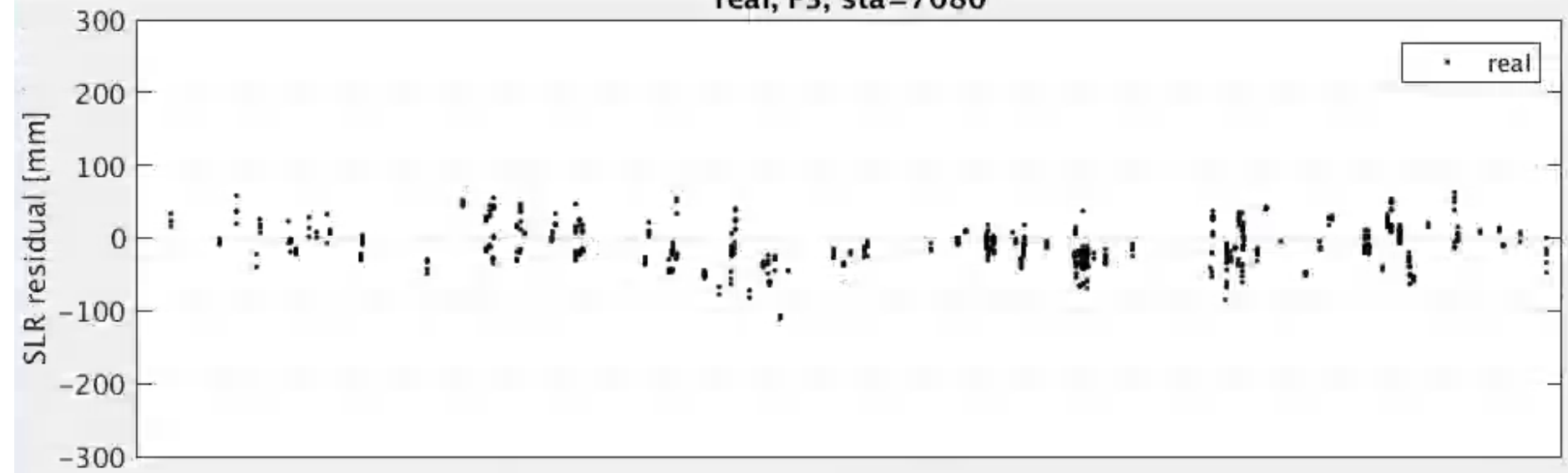




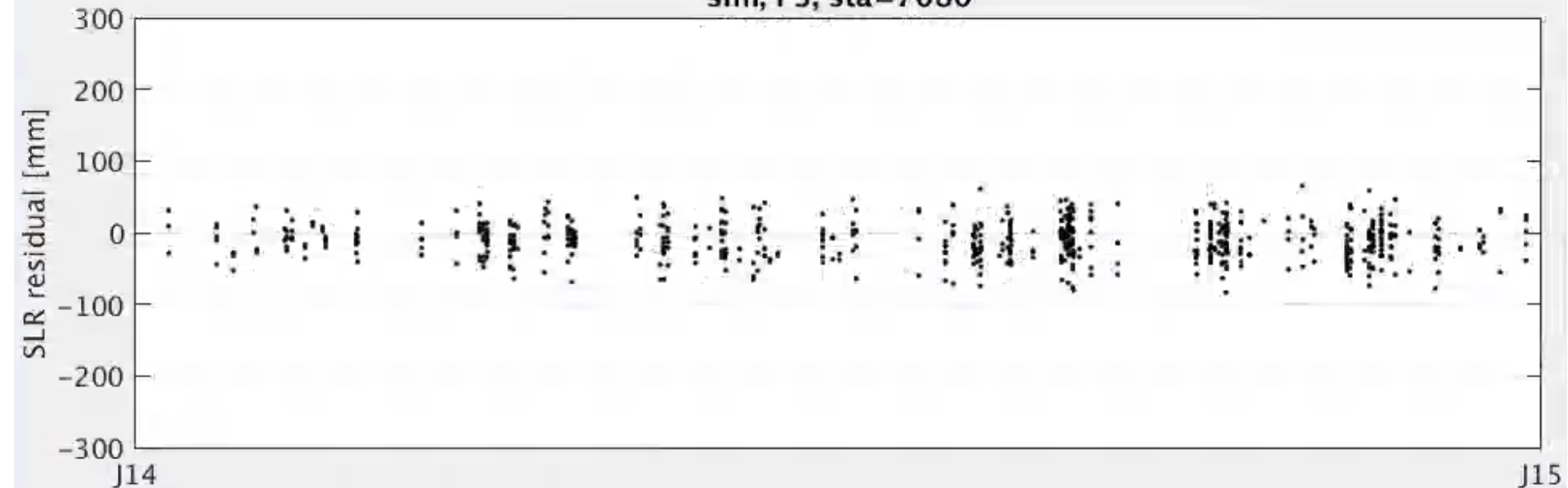
+

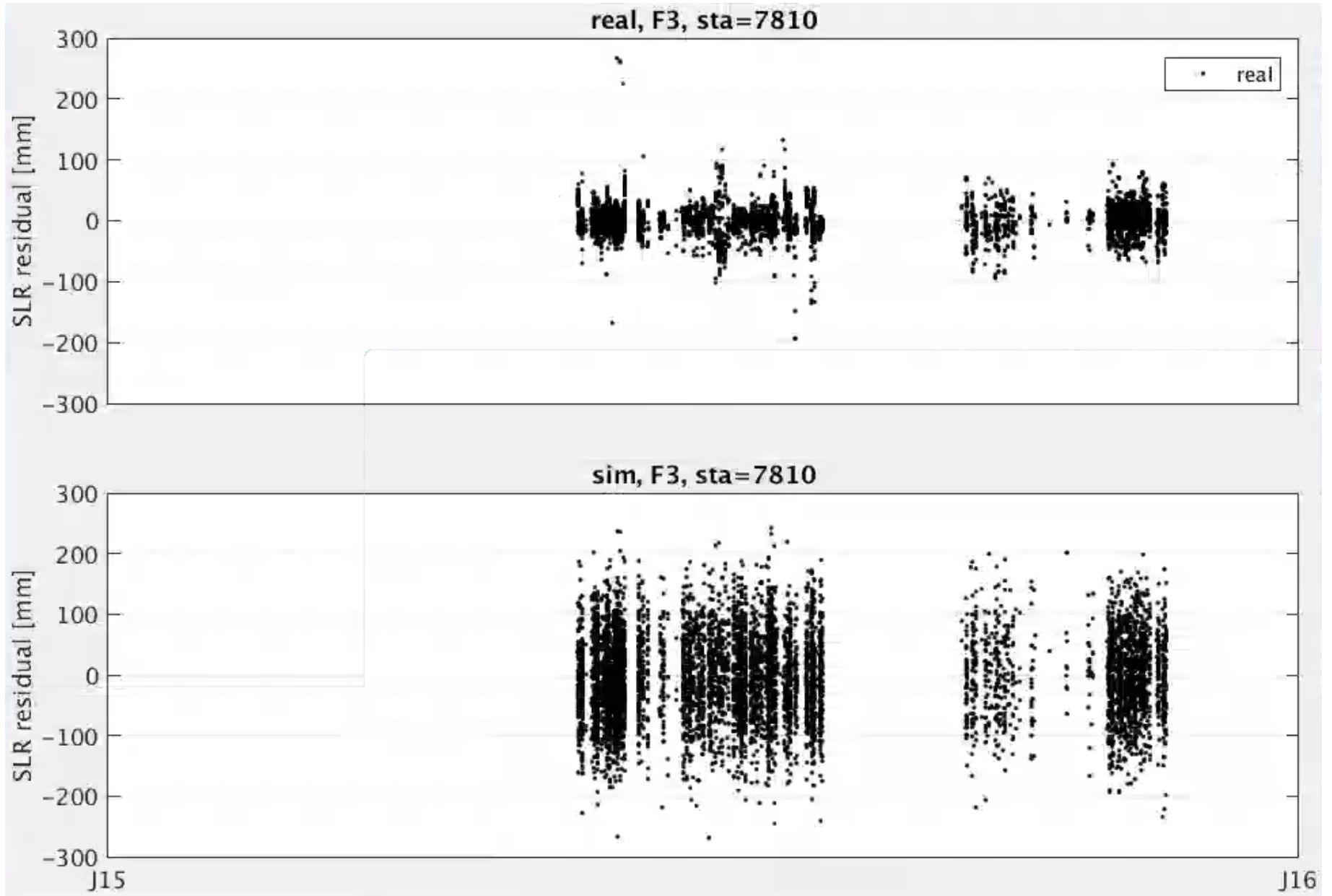


real, F3, sta=7080



sim, F3, sta=7080





# Conclusions & Outlook

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- Promising results that compare well in terms of residuals for existing observations.
- Different tracking strategies will be generated and used for comparison
- Investigating the impact of reducing observations to specific satellites in favor of more observations to others

**Thank you for your attention.**

# References

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- Dach, R., S. Lutz, P. Walser, P. Fridez (Eds); 2015: Bernese GNSS Software Version 5.2. User manual, Astronomical Institute, University of Bern, Bern Open Publishing. DOI: 10.7892/boris.72297; ISBN: 978-3-906813-05-9.
- Pearlman, M.R., Degnan, J.J., and Bosworth, J.M., "The International Laser Ranging Service", Advances in Space Research, Vol. 30, No. 2, pp. 135–143, July 2002, DOI:10.1016/S0273-1177(02)00277-6.